

T1-0018

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(11) Publication number: **0 634 640 A1**

(12)

EUROPEAN PATENT APPLICATION

(21) Application number: **94108238.0**

(51) Int. Cl.⁶: **G01N 1/30, C09B 23/02**

(22) Date of filing: **27.05.94**

(30) Priority: **28.05.93 JP 126651/93**

(43) Date of publication of application:
18.01.95 Bulletin 95/03

(84) Designated Contracting States:
DE ES FR GB IT

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(54) Method of counting reticulocytes.

(57) Asymmetric cyanine dyes (and their dimers) of generic formula:



where

A = 3-methyl-benzoxazolium or benzthiazolium iodide,

B = 4-(N-trimethylaminopropyl)-pyridinium or quinolinium iodide, and

n = 0 or 1

are used as fluorescent stains for staining reticulocytes in flow cytometric. A typical example is the thiazole orange dimer, TOTO-3. By suitable choice of components, the absorption maximum of the dye-RNA complex can be adjusted to allow the use of cheap, compact laser sources, e.g. Hc/Nc or laser diodes.

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FIELD OF THE INVENTION

This invention relates to a method of quantitating reticulocytes in blood. More particularly, the invention relates to a method and apparatus for quantitating reticulocytes with the aid of a dye suited for staining the ribonucleic acid (RNA) component of the reticulocytes.

BACKGROUND OF THE INVENTION

The immature erythrocytes in blood are called reticulocytes and the reticulocyte count is considered to be a laboratory parameter of great significance in the diagnosis of acute internal hemorrhage and hemolytic anemia, among other diseases. This is because reticulocytes serve as an indicator of blood cell production (erythrocyte differentiation).

It is also known that the reticulocyte has RNA, and in the determination of reticulocytes, it is common practice to stain a blood smear with new methylene blue (NMB), brilliant cresyl blue (BCB) or the like and count the stained reticulocytes under the microscope. There also are alternative procedures, either manual or automatic, which employ fluorescent dyes such as acridine orange, pyronine Y, thioflavin T, auramine O, thiazole orange and so on.

The ultraviolet staining technique using new methylene blue has been employed as the standard method for enumerating reticulocytes but being a manual procedure, this technique is time-consuming and complicated and has the drawback of individual difference according to different observers.

The determination technique employing acridine orange is either manual or automatic as disclosed in, *inter alia*, US Patents 4336029, 4325706 and 4284412. Thus, acridine orange couples itself to the RNA component of reticulocytes to produce a red fluorescence and the number of reticulocytes is determined by measuring the emissions. However, the RNA is precipitated by acridine orange and localized within the cell so that the quantitation of fluorescence tends to lack accuracy. Moreover, because this dye has a high affinity for the quartz cell and plastic materials constituting the circuitry of a flow cytometer.

Determination with pyronine Y requires a prior formalin fixation of red blood cells and is disadvantageous in that the technique is complicated and time-consuming. Furthermore, the fluorescent quantum efficiency of pyronine Y is so low that no sufficient sensitivity can be expected.

Thioflavin T is disclosed in Japanese Patent Application Kokai S-59-142465 as a reticulocyte stain but since it requires sufficient washing for reducing the noise of nonspecific fluorescence, determination with this dye has the disadvantage, that it requires a complicated and time-consuming procedure.

Auramine O and thiazole orange produce fluorescent emissions when excited by blue light but when a helium-cadmium laser is used as a light source in flow cytometry, the required equipment has to be large in size and expensive and the RNA specificity of these dyes is relatively lower than their specificity to DNA and protein.

Thus, the prior art determination techniques for enumerating reticulocytes using a flow cytometer have their own problems relating to sensitivity, accuracy and/or cost.

It is, therefore, a primary object of this invention to provide a means which enables sensitive, accurate and inexpensive determinations of reticulocytes using a dye suitable for staining reticulocytes.

SUMMARY OF THE INVENTION

This invention relates, in one aspect, to a method of quantitating reticulocytes which comprises exposing a blood sample stained with a fluorescent dye composition containing TOTO-3 or TO-PRO-3 as a fluorescent dye to light in the red wavelength region and measuring the fluorescence output from said blood sample.

This invention further relates, in a third aspect, to a method of quantitating reticulocytes which comprises exposing a blood sample stained with a fluorescent dye composition containing YOYO-1 or YO-PRO-1 as a fluorescent dye to light in the blue wavelength region and measuring the fluorescence output from said blood sample.

This invention relates, in a fourth aspect, to a method of quantitating reticulocytes which comprises exposing a blood sample stained with a fluorescent dye composition containing YOYO-3 or YO-PRO-3 as a fluorescent dye to light in the orange wavelength region and measuring the fluorescence output from said blood sample.

This invention further relates to a flow cytometric apparatus for practicing any of the above methods.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows the forward scatter versus red fluorescence cytogram and red fluorescence histogram of a normal blood sample stained with the fluorescent dye composition;

Fig. 2 shows the forward scatter versus red fluorescence cytogram and red fluorescence histogram of an abnormal blood sample stained with the fluorescent dye composition;

Fig. 3 shows the forward scatter versus red fluorescence cytogram and red fluorescence histogram of an unstained normal blood sample;

Fig. 4 shows the forward scatter versus orange fluorescence cytogram and orange fluorescence histogram of a normal blood sample stained with the fluorescent dye composition;

Fig. 5 shows the forward scatter versus orange fluorescence cytogram and orange fluorescence histogram of an abnormal blood sample stained with the fluorescent dye composition.

Fig. 6 shows the forward scatter versus orange fluorescence cytogram and orange fluorescence histogram of an unstained normal blood sample;

Fig. 7 shows the forward scatter versus green fluorescence cytogram and green fluorescence histogram of a normal blood sample stained with the fluorescent dye composition;

Fig. 8 shows the forward scatter versus green fluorescence cytogram and green fluorescence histogram of an abnormal blood sample stained with the fluorescent dye composition;

Fig. 9 shows the forward scatter versus green fluorescence cytogram and green fluorescence histogram of an unstained normal blood sample;

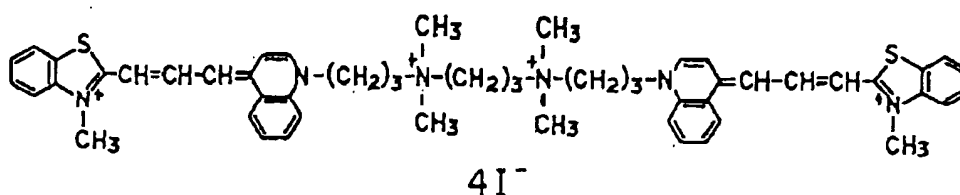
Fig. 10 shows the forward scatter versus orange fluorescence cytogram and orange fluorescence histogram of a normal blood sample stained with the fluorescent dye composition;

Fig. 11 shows the forward scatter versus orange fluorescence cytogram and orange fluorescence histogram of an abnormal blood sample stained with the fluorescent dye composition; and

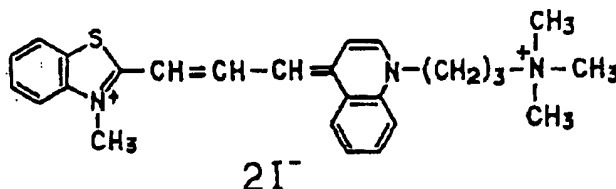
Fig. 12 shows the forward scatter versus orange fluorescence cytogram and orange fluorescence histogram of an unstained normal blood sample.

Fig. 13 shows construction of an apparatus for quantitating reticulocytes according to this invention.

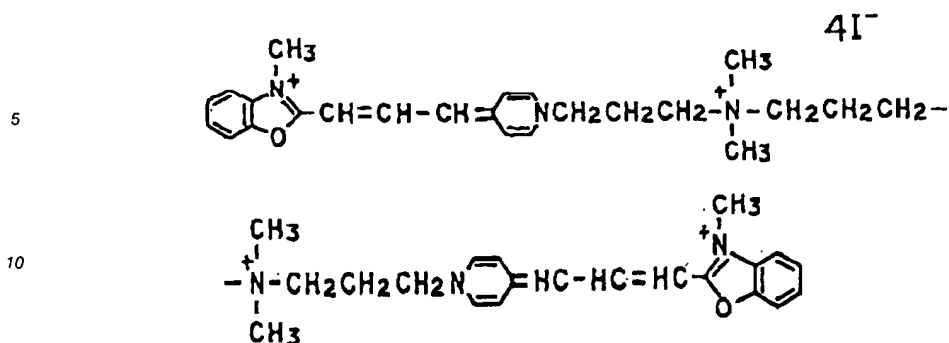
TOTO-3, the fluorescent dye which can be used in the first method, is a thiazole orange derivative homodimer of the following structure (chemical formula 1):



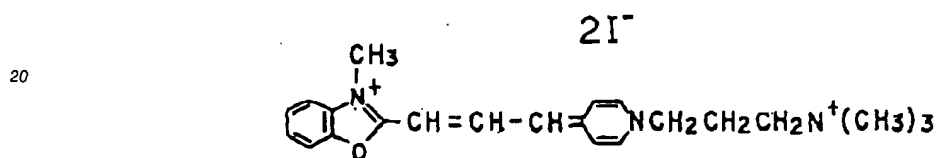
TO-PRO-3, which can also be used in the above method, is a quinolinium monomer of the following structure (chemical formula 2):



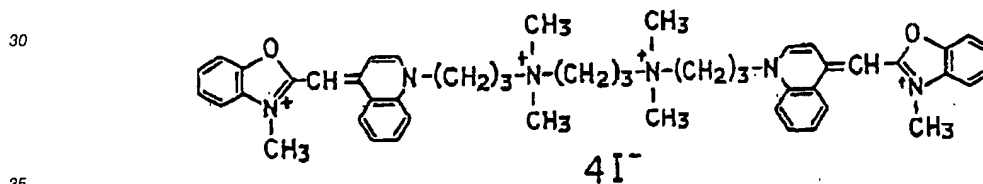
POPO-3, the fluorescent dye which can be used in the second method, is a dimerized benzoxazolium-4-pyridinium compound of the following structure (chemical formula 3):



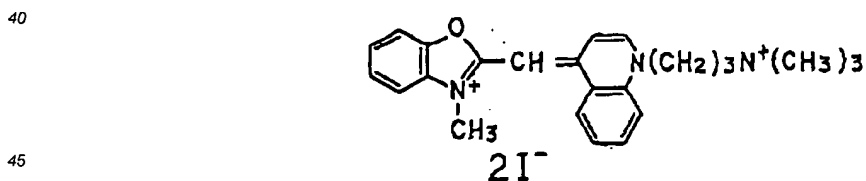
15 PO-PRO-3, which can also be used in the second method, is a benzoxazolium-4-pyridinium derivative of the following structure (chemical formula 4):



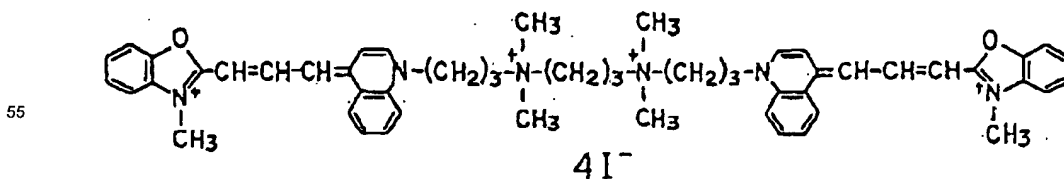
25 YOYO-1, the fluorescent dye which can be used in the third method, is a dimerized benzoxazolium-4-quinolinium compound of the following structure (chemical formula 5):



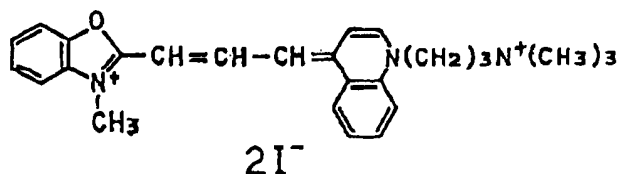
YO-PRO-1, which can also be used in the third method, is a benzoxazolium-4-quinolinium derivative of the following structure (chemical formula 6):



YOYO-3, the fluorescent dye which can be used in the fourth method, is a dimerized benzoxazolium-4-quinolinium compound of the following structure (chemical formula 7):



YO-PRO-3, the fluorescent dye which can also be used in the fourth method, is a benzoxazolium-4-quinolinium compound derivative of the following structure (chemical formula 8):



TOTO-3 and TO-PRO-3, POPO-3 and PO-PRO-3, YOYO-1 and YO-PRO-1, and YOYO-3 and YO-PRO-3, mentioned above, have all the advantage that whereas they produce little or no fluorescence when uncoupled to the RNA of reticulocytes, those compounds produce intense fluorescence when coupled to the RNA.

Therefore, in order to make the most of this advantage, the reticulocytes in blood are stained with a solution of TOTO-3 or TO-PRO-3, POPO-3 or PO-PRO-3, YOYO-1 or YO-PRO-1, or YOYO-3 or YO-PRO-3 in isotonic saline containing a small amount of dimethyl sulfoxide (DMSO)(each solution is hereinafter referred to as the fluorescent dye composition). The blood is stained on addition of such fluorescent dye composition and the stained blood gives a fluorescent emission on exposure to light depending on the wavelength of the exciting light, viz. the red wavelength when the dye is TOTO-3 or TO-PRO-3, the green wavelength in the case of POPO-3 or PO-PRO-3, the blue wavelength in the case of YOYO-1 or YO-PRO-1, or the orange wavelength in the case of YOYO-3 or YO-PRO-3, thus allowing reticulocytes in a blood sample to be detected and quantitated.

TOTO-3 or TO-PRO-3 has an excitation spectral peak at about 642 nm and a maximum peak of fluorescence at about 660 nm. Therefore, the light source for flow cytometry is preferably be a helium-neon laser (633nm) which is inexpensive, although a mercury lamp having an emission line of 615 nm, a red super bright LED, a red laser diode, a mercury-xenon lamp or the like can likewise be employed.

POPO-3 or PO-PRO-3 has an excitation spectral peak of about 540 nm and a maximum peak of fluorescence at about 570 nm. Therefore, in the flow cytometric determination with the dye, it is advantageous, cost-wise as well as efficiency-wise, to employ a green helium-neon laser having an excitation spectral peak at about 540 nm ($\lambda_p=543$ nm), a green super bright LED ($\lambda_p=567$ nm) or a green laser diode.

YOYO-1 or YO-PRO-1 has an excitation spectral peak at about 490 nm and a maximum peak of fluorescence at about 510 nm. Therefore, the light source for a flow cytometer is preferably an argon ion laser having an excitation spectral peak at about 490 nm ($\lambda_p=488$ nm), a blue super bright LED (Nichia Kagaku Kogyo, $\lambda_p=450$ nm) or a blue laser diode.

YOYO-3 or YO-PRO-3 has an excitation spectral peak at about 612 nm and a maximum peak of fluorescence at about 630 nm. Therefore, as the light source for a flow cytometer, on orange helium-neon laser having an excitation spectral peak at about 612 nm ($\lambda_p=594$ nm), an orange super bright LED and an orange laser diode are expedient, inexpensive and, therefore, advantageous.

Of course, as the light source for POPO-3 or PO-PRO-3, YOYO-1 or YO-PRO-1, or YOYO-3 or YO-PRO-3, a halogen lamp, a mercury-xenon lamp or the like can likewise be employed.

The fluorescent dye composition of this invention does not precipitate RNA and, therefore, the stained reticulocytes produce fluorescent emissions uniformly distributed within the cell. This means that an approximately first-order relation holds between the intensity of fluorescence of each reticulocyte and the RNA content of the same reticulocyte.

Clinically, the RNA content can be used as an indicator of differentiation of erythrocytes. Therefore, not only the reticulocyte count but also the fluorescence intensity data may provide new clinical information on the differentiation of red blood cells.

Thus, flow cytometry in accordance with this invention offers the advantage that both the reticulocyte count and the fluorescence intensity distribution can be determined at high speed, expediently and objectively. Of course, the method of this invention not only enables an automatic quantitation of reticulocytes but may be practiced on a manual mode.

In the field determination of reticulocytes by flow cytometry, the threshold value of red, green, blue or orange fluorescence is previously established using an unstained control (blank) sample, on enumeration is then performed using a stained sample and the reticulocytes satisfying the threshold value are counted.

Many flow cytometers are well known in the art and this invention is not limited to the use of any specific flow cytometer model.

EXAMPLES

The following examples are intended to illustrate some typical procedures for quantitation of reticulocytes according to this invention,

Example 1

A 1 mM stock fluorescent dye solution (TOTO-3 or TO-PRO-3/DMSO) is prepared. This stock solution is diluted 1:20 with isotonic phosphate buffer at pH 7.4 and 5 μ l of whole blood is added to 1 ml of the diluted fluorescent dye composition. The mixture is incubated at room temperature for about 30 minutes to prepare a blood sample and using a helium-neon laser having an excitation wavelength of 633 nm, the blood sample is subjected to flow cytometric determination.

Figs. 1 and 2 show the data generated by the above determination according to this invention for reticulocytes in the blood sample stained with the above-mentioned fluorescent dye compositions and Fig. 3 shows the data similarly generated for reticulocytes in the unstained blood sample. However, Fig. 1 represents the data on stained normal blood (a sample stained 1.6% with new methylene blue), showing the forward scatter versus red fluorescence cytogram and red fluorescence histogram for the normal blood sample. Fig. 2 represents the data for stained abnormal blood (a sample stained 4.9% with new methylene blue), showing the forward scatter versus red fluorescence cytogram and red fluorescence histogram for the abnormal blood. Fig. 3 represents the data for an unstained normal blood sample, similarly showing its forward scatter versus red fluorescence cytogram and red fluorescence histogram. In the computation of measured values, the threshold given in Fig. 3 was used in Figs. 1 and 2, with cells exceeding the threshold being regarded as reticulocytes.

Referring to Figs. 1 through 3, Fig. 3 represents results for the unstained blood, sample and provides control for the results in Figs. 1 and 2. The decisive difference between stained and unstained samples lies in the distribution of cells in staining analysis area A (Gate A in Fig. 1). A substantially single cluster is seen in Fig. 3 but as the result of staining the dominant cluster is shifted somewhat to the right and a subsidiary cluster appears to the right of the dominant cluster. This subsidiary cluster corresponds to the cell clusters of 1.9% and 5.7% seen in the positive areas of Figs. 1 and 2, respectively, which are clusters specifically stained with the fluorescent dye according to this invention. These results are quite similar to the results of the conventional determination using new methylene blue, suggesting the validity and usefulness of this invention.

Example 2

A 1 mM stock fluorescent dye solution (POPO-3 or PO-PRO-3/DMSO) is prepared. This stock solution is diluted 20-fold with isotonic phosphate buffer at pH 7.4 and 5 μ l of whole bloods is added to 1 ml of the diluted fluorescent dye composition. The mixture is incubated at room temperature for about 30 minutes and this sample is analyzed with a flow cytometer using a green helium-neon laser having an excitation wavelength of 543 nm, a green super bright LED or a green laser diode as the light source.

The data generated by the enumeration method of this invention are shown in Figs. 4 through 6. However, Fig. 4 represents the data for stained normal blood (a sample stained 1.6% with new methylene blue), showing the forward scatter versus orange fluorescence cytogram and orange fluorescence histogram of the normal blood. Fig. 5 represents the data generated with stained abnormal blood (a sample stained 5.3% with new methylene blue), similarly showing the forward scatter versus orange fluorescence cytogram and orange fluorescence histogram of the abnormal blood. Fig. 6 represents the data for the unstained normal blood sample, showing its forward scatter versus orange fluorescence cytogram and orange fluorescence histogram in a similar fashion.

Example 3

A 1 mM stock fluorescent dye solution (YOYO-1 or YO-PRO-1/DMSO) is diluted 20-fold with isotonic phosphate buffer at pH 7.4 and 5 μ l of whole blood is added to 1 ml of the diluted fluorescent dye composition. This system is incubated at room temperature for about 30 minutes to prepare a sample and flow cytometry is carried out using a blue argon ion laser having an excitation wavelength of 488 nm, a blue

super bright LED or a blue laser diode as the light source.

The data generated by the determination method of this invention are shown in Figs. 7 through 9. However, Fig. 7 represents the data for stained normal blood (a sample stained 1.6% with new methylene blue), showing its forward scatter versus green fluorescence cytogram and green fluorescence histogram. Fig. 8 represents the data for stained abnormal blood (a sample stained 5.3% with new methylene blue), similarly showing the forward scatter versus green fluorescence cytogram and green fluorescence histogram of abnormal blood, Fig. 9 represents the data for unstained normal blood, similarly showing its forward scatter versus green fluorescence cytogram and green fluorescence histogram.

10 Example 4

A 1 mM stock fluorescent dye solution (YOYO-3 or YO-PRO-3/DMSO) is diluted 20-fold with isotonic phosphate buffer at pH 7.4 and 5 μ l of whole blood is added to 1 ml of the diluted fluorescent dye composition. This system is incubated at room temperature for about 30 minutes and flow cytometry is performed using an orange helium-neon laser having an excitation wavelength of 594 nm, in orange super bright LED or an orange laser diode as the light source.

The data generated by the determination and analysis by the method of this invention are presented in Figs. 10 through 12. However, Fig. 10 represents the data for stained normal blood (a sample stained 1.6% with new methylene blue), showing the forward scatter versus red fluorescence cytogram and red fluorescence histogram of the normal blood. Fig. 11 represents the data for stained abnormal blood (a sample stained 5.3% with new methylene blue), similarly showing the forward scatter versus red fluorescence cytogram and red fluorescence histogram of abnormal blood. Fig. 12 represents the data for the unstained normal blood sample, showing the forward scatter versus red fluorescence cytogram and red fluorescence histogram of the normal blood.

Referring to Figs. 1 through 12 for the above Examples 1 through 4, the following abbreviations are used.

The apparatus according to this invention for quantitating reticulocytes is now described.

Referring to Fig. 13 which shows the construction of the apparatus for quantitating reticulocytes according to this invention, a blood sample 1 in a predetermined quantity is taken from a blood sampling tube 3 set in an autosampler 2 as the cap of the tube 3 is pierced by a cap piercer 4 driven by a driving mechanism not shown and a predetermined amount of blood is transferred from the blood sampling tube 3 by a blood dispensing pump 5. Then, a 3-way valve 6 is switched, whereupon the blood is transferred to a reaction vessel 7. Indicated by the numeral 8 is a dye bottle containing said fluorescent dye composition. The dye composition is metered out by a dye composition pump 9 and, on switching of a 3-way valve 10, transferred to the reaction vessel 7. In the reaction vessel 7, the blood sample and the dye composition are incubated together for a predetermined time, after which the mixture is withdrawn by a sample pump 11 and, on switching of a 3-way valve 12, is transferred to a flow cell 13. Connected to the flow cell 13 is a sheathed liquid pump 14 and according to the principle of hydrodynamic focusing, the blood sample 1 flows linearly on the central axis of the flow cell 13.

Disposed on one side of the flow cell 13 is a light source 15, e.g. a laser diode, and the beam of light L from the light source 15 irradiates the blood sample 1 in the flow cell 13. The resulting light signals are detected by a forward scatter sensor 16 disposed in the direction of advance of beam L and a fluorescence sensor 17 disposed in the direction perpendicular to the direction of advance of beam L. After the detection, the blood sample 1 is withdrawn from the flow cell 13 and transferred to an used blood tank 18.

A beam blocker 19 for avoiding direct light and a condensor 20 are interposed between the flow cell 13 and the forward scatter sensor 16. Furthermore, a condensor 21 and an interference filter 22 are interposed between the flow cell 13 and fluorescence sensor 17.

The light signals incident on said forward scatter sensor 16 and fluorescence sensor 17 are trimmed of noise and amplified in a signal processing circuit 23, digitalized in an A/D converter 24 and fed to an MPU 25. The MPU 25 is connected to various input-output devices such as a floppy disk drive 26, a keyboard 27, a CRT 28 and a printer 29. Moreover, the MPU 25 has the function to drive and control the blood dispensing pump 5, dye composition pump 9, sample pump 11, sheathed liquid pump 14, and a cleaning solution pump 31 for feeding a cleaning solution from a cleaning solution bottle 30 to the reaction vessel 7. After the reaction vessel 7 has been cleaned with the cleaning solution, a switch valve 32 is opened to drain the vessel.

Graph No. 1

- FW-SC : forward scatter intensity
- RD-FL : red fluorescence intensity
- 5 OR-FL : orange fluorescence intensity
- GR-FL : green fluorescence intensity
- Gate : enclosed area A, which is analyzed
- Count : number of cells
- Total : (sometimes abbreviated as Tot. Total % is the percentage relative to the total cell population indicated in Graph No. 1.
- 10 Mean X: mean of X-axis parameter values
- Mean Y: mean of Y-axis parameter values
- CV%X : coefficient of variation for X-axis parameter (S.D./mean)
- CV%Y : coefficient of variation for Y-axis parameter (S.D./mean)

Graph No. 2 and No.3

- Counts: The number of cells analyzed in the graph
- RD-FL : red fluorescence intensity
- 20 OR-FL : orange fluorescence intensity
- GR-FL : green fluorescence intensity
- REG : trigger area of data analysis. In this case, there are a positive area (+) and a negative area (-).
- Posi : positive %, representing the rate of positivity.
- 25 Count: number of cells present in each area
- Mean : mean of X-axis parameter values for cells present in each area
- SD : standard deviation of the values
- CV% : coefficient of variation [(S.D./mean) x 100].

As described above, the method of quantitating reticulocytes according to this invention comprises exposing a blood sample stained with a fluorescent dye composition containing TOTO-3 or TO-PRO-3, POPO-3 or PO-PRO-3, YOYO-1 or YO-PRO-1, or YOYO-3 or YO-PRO-3 as the fluorescent dye to light in the red wavelength region in the case of TOTO-3 or TO-PRO-3, light in the green wavelength region in the case of POPO-3 or PO-PRO-3, light in the blue wavelength region in the case of YOYO-1 or YO-PRO-1 or light in the orange wavelength region in the case of YOYO-3 or YO-PRO-3 and measuring the output fluorescence from said blood sample to thereby quantitate reticulocytes with high sensitivity and accuracy and at low cost.

Furthermore, the flow cytometry according to this invention, employing a blood sample stained with the above fluorescent dye composition, offers the advantage of expedient reticulocyte quantitation with good sensitivity with a minimum of fluorescent background. Moreover, because the staining is performed with a composition containing the above-mentioned fluorescent dye, the intracellular RNA of reticulocytes is not precipitated and a first-order relation can be obtained between RNA content and fluorescence intensity, thus offering the advantage of providing clinically useful information.

Furthermore, the light source corresponding to the excitation wavelength of the fluorescent dye composition, viz. a red helium-neon laser, a red super bright LED or a red laser diode can be utilized for TOTO-3 or TO-PRO-3, a green helium-neon laser, a green super bright LED or a green laser diode for POPO-3 or PO-PRO-3, a blue argon ion laser, a blue super bright LED or a blue laser diode for YOYO-1 or YO-PRO-1, or an orange helium-neon laser, an orange super bright laser or and orange laser diode for YOYO-3 or YO-PRO-3, so that compared with flow cytometry using a discharge type laser as the light source, the equipment necessary for determination may be reduced in size, less costly and simple in construction.

Claims

1. A method of quantitating reticulocytes which comprises exposing a blood sample stained with a fluorescent dye composition containing TOTO-3 or TO-PRO-3 as the fluorescent dye to light in the red wavelength region and measuring the output fluorescence from said blood sample.

2. A method of quantitating reticulocytes which comprises exposing a blood sample stained with a fluorescent dye composition containing POPO-3 or PO-PRO-3 as the fluorescent dye to light in the green wavelength region and measuring the output fluorescence from said blood sample.
- 5 3. A method of quantitating reticulocytes which comprises exposing a blood sample stained with a fluorescent dye composition containing YOYO-1 or YO-PRO-1 as the fluorescent dye to light in the blue wavelength region and measuring the output fluorescence from said blood sample.
- 10 4. A method of quantitating reticulocytes which comprises exposing a blood sample stained with a fluorescent dye composition containing YOYO-3 or YO-PRO-3 as the fluorescent dye to light in the orange wavelength region and measuring the output fluorescence from said blood sample.
- 15 5. The method of quantitating reticulocytes according to claim 1 wherein reticulocytes in the blood sample stained with said fluorescent dye composition are quantitated by flow cytometry using light from a helium-neon laser.
- 20 6. The method of quantitating reticulocytes according to claim 1 wherein reticulocytes in the blood sample stained with said fluorescent dye composition are quantitated by flow cytometry using light from a super bright LED.
- 25 7. The method of quantitating reticulocytes according to claim 1 wherein reticulocytes in the blood sample stained with said fluorescent dye composition are quantitated by flow cytometry using light from a laser diode.
- 30 8. The method of quantitating reticulocytes according to claim 2 wherein reticulocytes in the blood sample stained with said fluorescent dye composition are quantitated by flow cytometry using light from a helium-neon laser.
- 35 9. The method of quantitating reticulocytes according to claim 2 wherein reticulocytes in the blood sample stained with said fluorescent dye composition are quantitated by flow cytometry using light from a super bright LED.
- 40 10. The method of quantitating reticulocytes according to claim 2 wherein reticulocytes in the blood sample stained with said fluorescent dye composition are quantitated by flow cytometry using light from a laser diode.
- 45 11. The method of quantitating reticulocytes according to claim 3 wherein reticulocytes in the blood sample stained with said fluorescent dye composition are quantitated by flow cytometry using light from a helium-neon laser.
- 50 12. The method of quantitating reticulocytes according to claim 3 wherein reticulocytes in the blood sample stained with said fluorescent dye composition are quantitated by flow cytometry using light from a super bright LED.
- 55 13. The method of quantitating reticulocytes according to claim 3 wherein reticulocytes in the blood sample stained with said fluorescent dye composition are quantitated by flow cytometry using light from a laser diode.
14. The method of quantitating reticulocytes according to claim 4 wherein reticulocytes in the blood sample stained with said fluorescent dye composition are quantitated by flow cytometry using light from a helium-neon laser.
15. The method of quantitating reticulocytes according to claim 4 wherein reticulocytes in the blood sample stained with said fluorescent dye composition are quantitated by flow cytometry using light from a super bright LED.
16. The method of quantitating reticulocytes according to claim 4 wherein reticulocytes in the blood sample stained with said fluorescent dye composition are quantitated by flow cytometry using light from a laser

diode.

17. An apparatus for quantitating reticulocytes by staining reticulocytes in blood with a fluorescent dye and analyzing the result, comprising

5 a blood sample distributing means which dispenses blood samples directly from a blood collecting tube,

10 a blood sample staining means for adding a fluorescent dye composition containing TOTO-3 or TO-PRO-3, POPO-3 or PO-PRO-3, YOYO-1 or YO-PRO-1, or YOYO-3 or YO-PRO-3 as the fluorescent dye to the blood sample dispensed by said blood sample distribution means to thereby stain the blood sample,

a flow cell through which the stained blood sample flows,

a means for irradiating a beam of light to the sample flowing through said flow cell,

a cell light information detection means for detecting at least two cell light data available from the blood sample irradiated by said beam of light,

15 a cell light information processing means for processing the cell light information detected by said cell light detection means, and

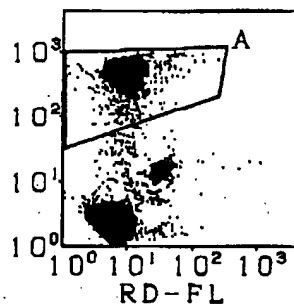
an output means for outputting results of said processing by said cell light information processing means.

- 20 18. The apparatus for quantitating reticulocytes according to claim 17 wherein a laser diode, a super bright LED, a helium-neon laser or an argon ion laser is used as said light source.

FIG. 1

FW-SC

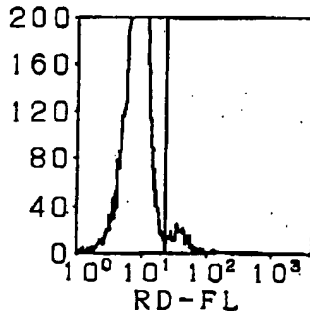
Graph No. 1



Gate	Count	Total%	MeanX	MeanY	CV%X	CV%Y
Tot	31,260	100.0	52.6	78.6	39.9	95.2
A	10,002	32.0	57.8	181.8	27.0	9.4
B						
C						

Counts

Graph No. 2

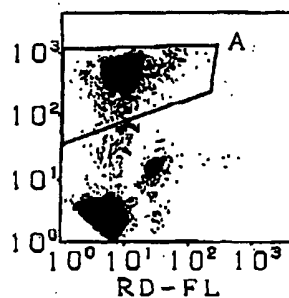


REG	Posi%	Count	Mean	SD	CV%
-	98.1	9,815	57.1	13.3	23.3
+	1.9	187	116.7	13.7	11.7

FIG. 2

FW-SC

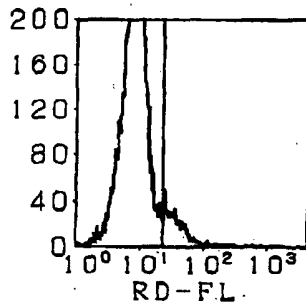
Graph No. 1



Gate	Count	Total%	MeanX	MeanY	CV%X	CV%Y
Tot	58,592	100.0	58.4	48.2	36.0	136.1
A	10,210	17.4	65.8	182.4	27.1	9.1
B						
C						

Counts

Graph No. 2

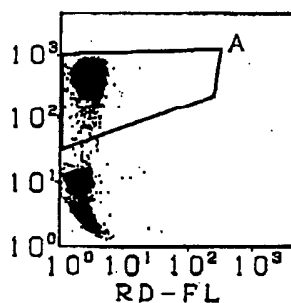


REG	Posi%	Count	Mean	SD	CV%
-	94.3	9,631	63.4	13.0	20.5
+	5.7	579	115.2	14.4	12.5

FIG. 3

FW-SC

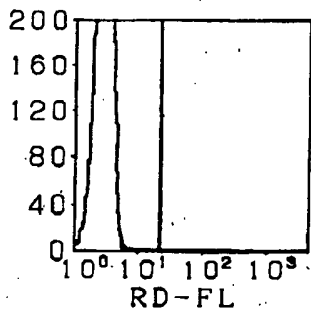
Graph No. 1



	Gate	Count	Total%	MeanX	MeanY	CV%X	CV%Y
Tot		16,571	100.0	29.6	132.4	44.6	50.8
A		10,000	60.3	31.8	184.2	28.3	8.5
B							
C							

Counts

Graph No. 2

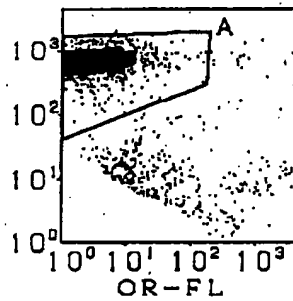


REG	Posi%	Count	Mean	SD	CV%
-	100.0	9,996	32.2	8.8	27.3
+	0.0	4	118.0	6.3	5.3

FIG. 4

FW-SC

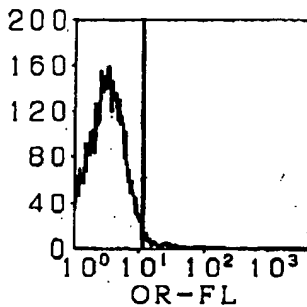
Graph No. 1



Gate	Count	Total%	MeanX	MeanY	CV%X	CV%Y
Tot	10,603	100.0	27.2	183.2	14.0	15.8
A	10,001	94.3	22.8	189.8	99.1	4.1
B						
C						

Counts

Graph No. 3

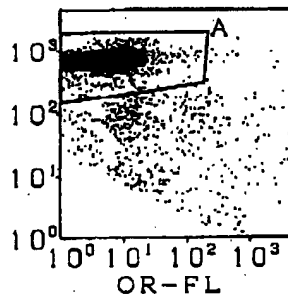


REG	Posi%	Count	Mean	SD	CV%
-	97.9	9,790	21.7	20.8	95.9
+	2.1	211	87.1	17.2	19.7

FIG. 5

FW-SC

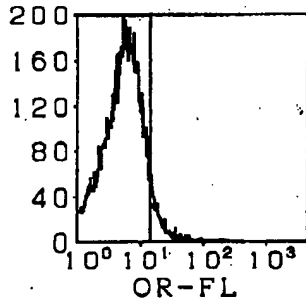
Graph No. 1



	Gate	Count	Total%	MeanX	MeanY	CV%X	CV%Y
	Tot	10,827	100.0	46.4	182.4	68.1	14.4
	A	9,681	89.4	42.0	190.4	61.4	3.7
	B						
	C						

Counts

Graph No. 3

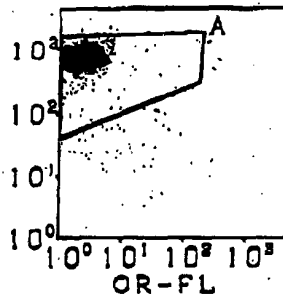


REG	Posi%	Count	Mean	SD	CV%
-	92.4	8,949	38.8	22.9	59.0
+	7.6	732	88.3	13.9	15.7

FIG. 6

FW-SG

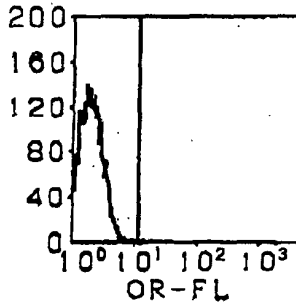
Graph No. 1



	Gate	Count	Total%	MeanX	MeanY	CV%X	CV%Y
	Tot	10,070	100.0	8.8	190.2	159.1	5.9
	A	10,001	99.3	8.4	190.8	152.4	4.4
	B						
	C						

Counts

Graph No. 3

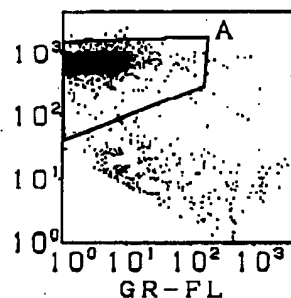


REG	Pos%	Count	Mean	SD	CV%
-	99.9	9,993	8.5	12.7	149.4
+	0.1	8	105.9	23.2	21.9

FIG. 7

FW-SC

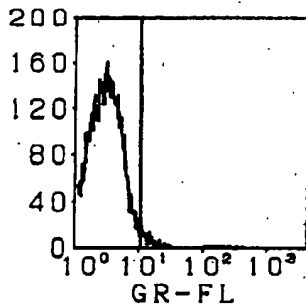
Graph No. 1



Gate	Count	Total%	MeanX	MeanY	CV%X	CV%Y
Tot	10,691	100.0	26.8	182.6	112.7	16.4
A	10,001	93.5	22.4	190.0	100.0	4.1
B						
C						

Counts

Graph No. 3

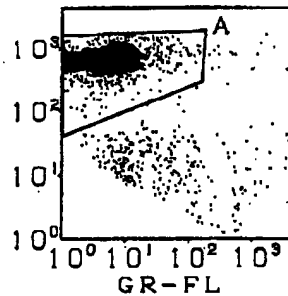


REG	Posi%	Count	Mean	SD	CV%
-	97.7	9,771	21.3	20.4	95.8
+	2.3	230	85.9	17.4	20.3

FIG. 8

FW-SC

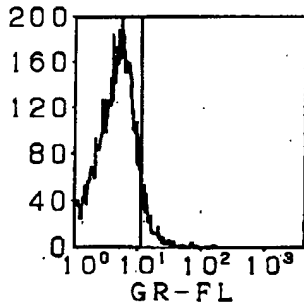
Graph No. 1



Gate	Count	Total%	MeanX	MeanY	CV%X	CV%Y
Tot	10,478	100.0	39.6	183.6	78.3	13.6
A	10,003	95.5	36.6	188.4	70.5	4.2
B						
C						

Counts

Graph No. 3

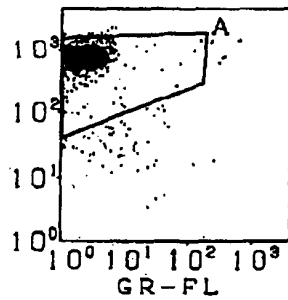


REG	Posi%	Count	Mean	SD	CV%
-	92.4	9,241	33.1	22.6	68.3
+	7.6	762	84.3	15.4	18.3

FIG. 9

FW-SC

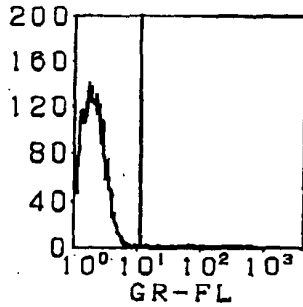
Graph No. 1



	Gate	Count	Total%	MeanX	MeanY	CV%X	CV%Y
Tot	10.070	100.0	8.8	190.2	159.1	5.9	
A	10.001	99.3	8.4	190.8	152.4	4.4	
B							
C							

Counts

Graph No. 3

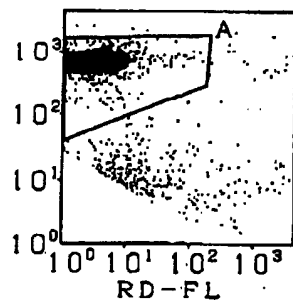


REG	Posi%	Count	Mean	SD	CVX
-	99.9	9,993	8.5	12.7	149.4
+	0.1	8	105.9	23.2	21.9

FIG. 10

FW-SC

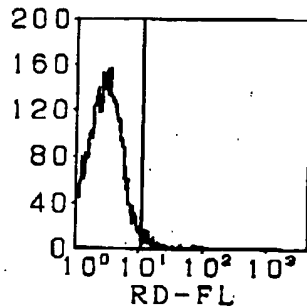
Graph No. 1



Gate	Count	Total%	MeanX	MeanY	CV%X	CV%Y
Tot	10,601	100.0	25.0	183.4	117.6	15.3
A	10,001	94.3	21.0	189.8	102.9	3.8
B						
C						

Counts

Graph No. 3

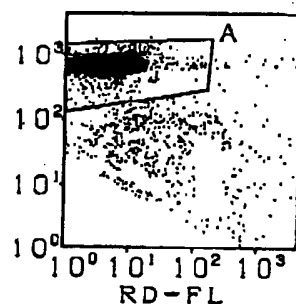


REG	Posi%	Count	Mean	SD	CV%
-	98.1	9,815	20.0	19.9	99.5
+	1.9	186	86.8	17.3	19.9

FIG. 11

FW-SC

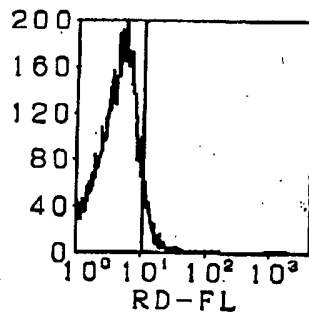
Graph No. 1



Gate	Count	Total%	MeanX	MeanY	CV%X	CV%Y
Tot	11,007	100.0	41.4	181.2	76.8	15.6
A	9,771	88.8	36.2	190.4	68.5	3.7
B						
C						

Counts

Graph No. 3

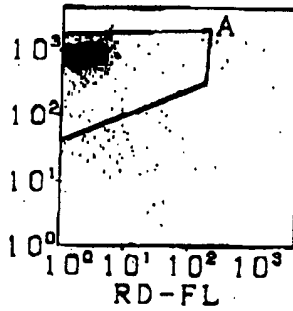


REG	Posi%	Count	Mean	SD	CV%
-	92.9	9,075	33.2	22.1	66.6
+	7.1	696	81.5	14.7	18.0

FIG. 12

FW-SC

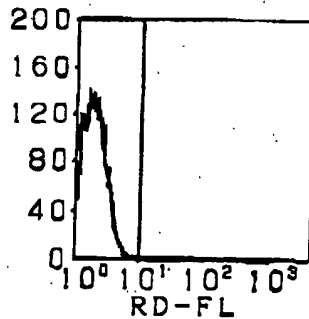
Graph No. 1



Gate	Count	Total%	MeanX	MeanY	CV%X	CV%Y
Tot	10,070	100.0	8.8	190.2	159.1	5.9
A	10,001	99.3	8.4	190.8	152.4	4.4
B						
C						

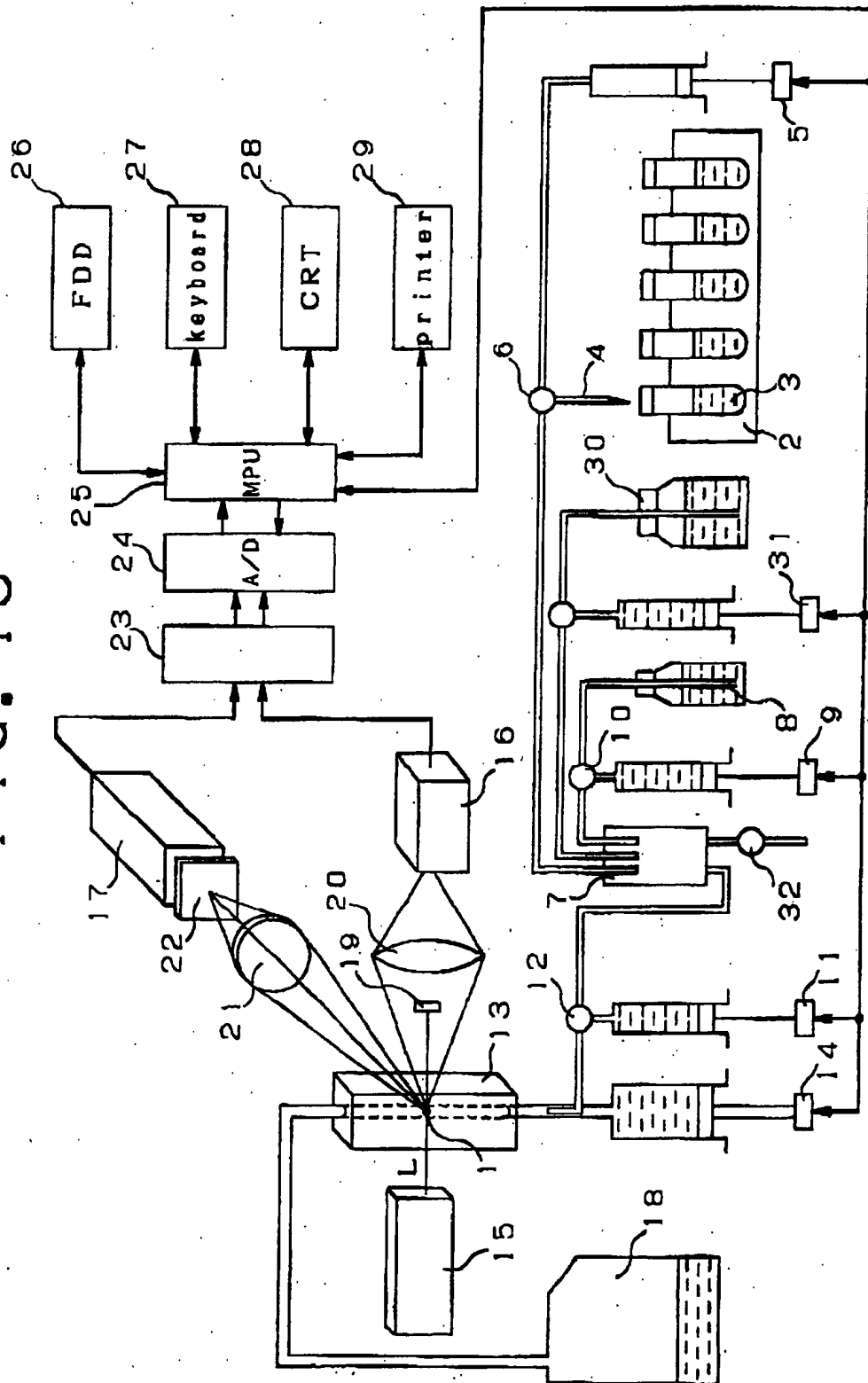
Counts

Graph No. 3



REG	Posi%	Count	Mean	SD	CV%
-	99.9	9,993	8.5	12.7	149.4
+	0.1	8	105.9	23.2	21.9

FIG. 13





European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 94 10 8238

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
X Y A	WO-A-93 06482 (MOLECULAR PROBES INC) * page 1, line 9 - page 2, line 3; page 3, line 22 - page 6, line 17; examples 1-3, 7* ---	1,3,4 6,7,9, 10,12, 13,15-18 2,5,8, 11,14	G01N1/30 C09B23/02
Y A	DATABASE WPI Section Ch, Week 9325, Derwent Publications Ltd., London, GB; Class B04, AN 93-199619 & JP-A-05 040 097 (HITACHI CHEM CO LTD) 19 February 1993 * abstract * ---	6,7,9, 10,12, 13,15,16 18	
Y A	US-A-4 883 867 (LEE L G ET AL) * column 2, line 14 - column 6, line 40 * ---	17,18 1,3,4	TECHNICAL FIELDS SEARCHED (Int.Cl.5)
D,A	US-A-4 325 706 (GERSHMAN R J ET AL) * column 2, line 39 - column 12, line 20; figure 1 * ---	5,8,11, 14,17,18	G01N C09B
A	NUCLEIC ACIDS RESEARCH, vol.20, no.11, 1992, OXFORD GB pages 2803 - 2812 RYE S R ET AL: 'Stable fluorescent complexes of double-stranded DNA with bis-intercalating asymmetric cyanine dyes: properties and applications' * abstract; figure 1 * --- -/--	1,3,4	
The present search report has been drawn up for all claims			
Place of search BERLIN		Date of completion of the search 4 October 1994	Examiner Johnson, K
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons ----- & : member of the same patent family, corresponding document			



European Patent
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EUROPEAN SEARCH REPORT

Application Number
EP 94 10 8238

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
E	US-A-5 321 130 (HAUGLAND R P ET AL) * the whole document * ---	1-16	
P,A	DATABASE WPI Section Ch, Week 9348, Derwent Publications Ltd., London, GB; Class B02, AN 93-383255 & JP-A-5 287 209 (HITACHI CHEM CO LTD) 2 November 1993 * abstract * -----	1,3,4,6, 7,9,10, 12,13, 15-18	
			TECHNICAL FIELDS SEARCHED (Int.Cl.5)
The present search report has been drawn up for all claims			
Place of search BERLIN		Date of completion of the search 4 October 1994	Examiner Johnson, K
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons ----- & : member of the same patent family, corresponding document	